NASA TECH BRIEF

Goddard Space Flight Center

Micrometeoroid Velocity-and-Trajectory Analyzer

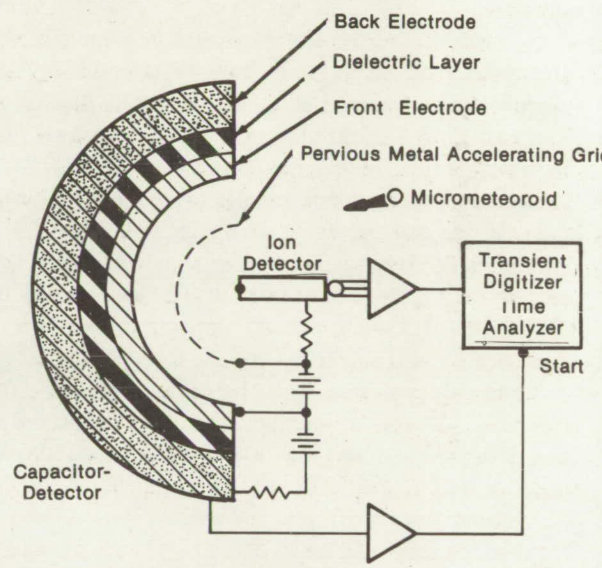
The problem:

Mass spectrometry techniques have been used to ascertain the abundance of elements and isotopes in microscopic moving particles. Particles to be analyzed include micrometeoroids, droplets in atmospheric clouds, and ejecta from hypervelocity missile impacts or jet engine exhausts. In devices using these techniques, a microscopic particle impacting on the front face of an electrically-biased metallic surface such as tungsten produces positive ions which are directed to an ion detector by an electrostatic field. The kinetic energy of an impacting particle on the metal surface results in a portion of the particle being vaporized and ionized. Since only the kinetic energy of the particle causes vaporization and ionization, the devices have a relatively low efficiency, particularly for particles of low impact velocity (less than 5 km/s).

Another difficulty with such devices is that the elements in a particle which can be ionized most readily are disproportionately represented in the mass spectrum. Further, a phenomenon known as ghost spectra frequently occurs as a result of fragments of a particle impacting on metal parts, other than the impact surface, that are located in the impact surface housing. In response to such impacts, fragmentary particles may be produced which reach the impact surface slightly after the impact of the main part of the particle, producing ions from the impact surface at slightly-displaced time intervals. Because of the different travel times of ions of different elements from the impact surface to the ion detector, it is difficult to distinguish between ions derived from the main part of the particle and from fragments.

The solution:

By adding the potential energy of a charged capacitor to the kinetic energy of the impacting particle, a new technique causes a major fraction (10 to 100 percent) of the atoms in a microscopic particle impacting on a particle-receiving surface to be ionized.



Micrometeoroid Composition Analyzer

How it's done:

The principal part of the new composition analyzer (see figure) is a capacitor consisting of a front electrode upon which the particle impacts, a rear electrode, and a solid dielectric sandwiched between the two. The front and back electrodes, as well as the dielectric and an accelerating grid, are accurately-shaped concentric segments of spherical shells having a common center and different radii. An ion detector is located approximately at the common center of the different spheres so that substantially all of the ions

(continued overleaf)

ejected from the front electrode impinge on the detector with a minimum amount of focusing required. The front electrode and the dielectric together have a thickness such that an impinging microscopic particle can penetrate them both. This is achieved by forming the front electrode from a thin metal film, having a thickness typically on the order of 0.1 μm. The metal film is deposited on an oxide dielectric layer, having a thickness between 0.4 and 1 μm, that in turn is formed on a doped semiconductor substrate which comprises the rear electrode.

In response to a particle impacting on the front electrode, the front and back electrodes become electrically connected and are quickly discharged. The resulting discharge spark causes positive ions to be ejected from the front electrode. These positive ions are formed from elements in the impinging particle, as well as from elements contained in the materials of the capacitor. Thus, it is preferable to employ capacitor materials that do not include elements that are normally expected to be in the particles to be analyzed.

To enable positive ions to be ejected from the front electrode of the capacitor, the front electrode is negatively biased relative to the back electrode. The positive ions ejected from the front electrode are then accelerated by an electric field that is established in front of the front electrode by a grid that is pervious to the particles as well as to the ions. The grid is positioned between the front electrode and an ion detector that is biased so that substantially all ions passing through the grid travel to the ion detector. The positive ions produce an ion current pulse that has been found to have a peak value on the order of 10 to 50 A and a duration on the order of 100 ns. The 10-A to 50-A ion current is to be contrasted with ion currents of approximately 100 nA as generated by previous devices.

The output of the ion detector is suitably connected to the transient digitizer time analyzer. The time arrival of the pulses at the ion detector, relative to the impact time of the particle, provides an indication of the mass of the ions received by the detector and thereby of the constituent atoms of the particle.

The capacitor has a relatively-slow response time, since it becomes so completely discharged in response to an impacting particle that it cannot recover for approximately 10 to 100 ms subsequent to the impact. Therefore the ions derived from the front electrode, as a result of fragments of the same particle which caused an initial ionization, are not produced in sufficient quantities relative to the number of ions resulting from the initial impact to be detected. Ghost spectra are thus substantially eliminated.

By converting a major fraction of the atoms in the particle into ions, the signal-to-noise ratio of the detected mass spectrum is improved by orders of magnitude over that of previous analyzers. The need for complex and costly electronic circuitry is thus obviated. Because the capacitor supplies potential energy to the impacting particle, which is added to the relatively low kinetic energy of such particles, the new technique can also be used to analyze particles having relatively low impact velocities (as low as or lower than 1 km/s). Moreover, in contrast to previous techniques, the chemical constituents of an impacting particle are represented by the generated ion mass spectrum in approximately the correct proportions.

Note:

Requests for further information may be directed to:

Technology Utilization Officer
Goddard Space Flight Center
Code 207.1
Greenbelt, Maryland 20771
Reference: TSP74-10286

Patent status:

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to:

Patent Counsel
Goddard Space Flight Center
Code 204
Greenbelt, Maryland 20771

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